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Study on Natural Frequencies Due to Inclined Crack with Variable Angles of Inclination and Varying Crack Depths Using Vibration Analysis

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Abstract

An important assignment for engineers is to determine the effect of the damage like inclined cracks on the stability characteristic of beam structure. The Cracks in vibrating component can initiate catastrophic failures. The presences of cracks change the physical characteristics of a structure which in turn alter its dynamic response characteristics. Therefore there is need to understand dynamics of cracked structures. This paper focuses on the vibration analysis of a beam with fixed free boundary condition and investigates the mode shape and its frequency. Finite element analysis using ANSYS software is adopted for the dynamic behavior of the beam. Variations of natural frequencies due to inclined crack with variable angles of inclination and with varying crack depths have been studied. The analysis is performed using ANSYS software.

I. INRODUCTION

It is required that structures must safely work during its service life. But, damages initiate a breakdown period on the structures. Cracks are among the most encountered damage types in the structures. Cracks in a structure may be hazardous due to static or dynamic loadings, so that crack detection plays an important role for structural health monitoring applications. Beam type structures are being commonly used in construction and machinery industries. In the literature, several studies deal with the structural safety of beams, especially, crack detection by structural health monitoring. Studies based on structural health monitoring for crack detection deal with change in natural frequencies and mode shapes of the beam. The most common structural defect is the existence of a crack. Cracks are present in structures due to various reasons. The presence of a crack could not only cause a local variation in the stiffness but it could affect the mechanical behavior of the entire structure to a considerable extent. Cracks may be caused by fatigue under service conditions as a result of the limited fatigue strength. They may also occur due to mechanical defects. Another group of cracks are initiated during the manufacturing processes. Generally they are small in sizes. Such small cracks are known to propagate due to fluctuating stress conditions. If these propagating cracks remain undetected and reach their critical size, then a sudden structural failure may occur. To avoid the unexpected or sudden failure, earlier crack detection is essential. Taking this ideology into consideration crack detection is one of the most important domains for many researchers. Many researchers to develop various techniques for early detection of crack location, depth, size and pattern of damage in a structure. Many non-destructive methodologies for crack detection have been in use worldwide. However the vibration based method is fast and inexpensive for crack/damage identification. Hence it is possible to use natural frequency measurements to detect cracks. Dayal. R. Parhi, Prases. K. Mohanty, Sasmita Sahu and Amiya Kumar Dash have presented analytical as well as experimental methods to locate and quantify the size of damage in beam type structure from vibration mode.[1] Kaustubha V. Bhinge et. al, tried to establish a systematic approach to study and analyze the crack in cantilever beam. It is addresses the inverse problem of assessing the crack location and crack size in various beam structures. The study is based on measurement of natural frequency, a global parameter that can be easily measured at any point conveniently on the structure.[2] D.Y. Zheng, N.J. Kessissoglou have studied on the natural frequencies and mode shapes of a cracked beam are obtained using the finite element method. An ‘overall additional flexibility matrix’, instead of the ‘local additional flexibility matrix’, is added to the flexibility matrix of the corresponding intact beam element to obtain the total flexibility matrix, and therefore the stiffness matrix.[3] Malay Quila et. al., have studied on cracks which causes changes in the physical properties of a structure which introduces flexibility, and thus reducing the stiffness of the structure with an inherent reduction in modal natural frequencies. Consequently it leads to the change in the dynamic response of the beam.[4] Ranjan K. Behera, Anish Pandey, Dayal R. Parhi in their research work has developed the theoretical expressions to find out the natural frequencies and mode shapes for the cantilever beam with two transverse cracks.[5] E. Bahmyari, S. R. Mohebpour, and P. Malekzadeh have investigated on the dynamic response of laminated composite beams subjected to distributed moving masses using the finite element method (FEM) based on the both first-order shear deformation theory (FSDT) and the classical beam theory (CLT). Six and ten degrees of freedom beam elements are used to discretize the CLT and FSDT equations of motion, respectively using Newmark's scheme.[8] As discussed above the failure of machine component is loss of time, money and life. Most of the machine components failures are because of the crack. So there is necessity to predict such failures in advance so that losses because of failure are avoided or minimized. Condition based monitoring is one of the preventive maintenance method used in the plant maintenance. So there is requirement to develop the methodology which can be used easily to predict the crack in the machine component from the machine condition such as vibration data. The present work is aimed at finding the natural frequency of a cantilever and simply supported beam with a single inclined crack with variation in angles and un-cracked using finite element analysis ANSYS software.

All standard paper components have been specified for three reasons: (1) ease of use when formatting individual papers, (2) automatic compliance to electronic requirements that facilitate the concurrent or later production of electronic products, and (3) conformity of style throughout conference proceedings. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. FINITE ELEMENT ANALYSIS

The finite element method (FEM) is a numerical method for analyzing structures. It is firmly established as a powerful popular analysis tool. It is most widely used in structural mechanics. The finite element procedure produces many simultaneous algebraic equations, which are generated and solved on a digital computer. The main rule that involved in finite element method is "DEVIDE and ANALYZE". The greatest unique feature which separates finite element method from other methods is "It divides the entire complex geometry into simple and small parts, called "finite elements". These finite elements are the building blocks of the finite element analysis. Based on the type of analysis going to be performed, these elements divided into several types. Division of the domain into elements is called "mesh". The forces and moments are transferred from one element to next element are represented by degrees of freedom (DOFs) at coordinate locations which are called as "nodes". Approximate solutions of these finite elements give rise to the solution of the given geometry which is also an approximate solution.

The approximate solution becomes exact when

1. The geometry is divided into numerous or infinite elements.
2. Each element of geometry must define with a complete set of polynomials (infinite terms).

The finite element method has become an important tool for the numerical solution of a wide range of engineering problems. It has developed simultaneously with the increasing use of high-speed electronic digital computers and with the growing emphasis on numerical methods for engineering analysis. This method started as a generalization of the structural idea to some problems of elastic continuum, is well-established numerical method applicable to any continuum problem, stated in terms of differential equations or as an extranet problem.

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Table 2.1: Material Property and Dimensions of Aluminium Beam

Dimensions and Properties	Aluminum
Length	0.4 m
Width	0.03 m
Thickness	0.006 m
Density	2700 kg/m^3
Young modulus	70 Gpa
Poisson’s ratio	0.3

III. MODELLING OF BEAM USING ANSYS

The Beam is modeled in ANSYS Software. Element SOLID45 is used for the 3-D modeling of solid structures. Material properties are provided which is briefly listed in

Table 1. After that 12 models are prepared with various inclination angles for crack with the location of crack as L/2 of beam. After that the beam is meshed (Fig. 2). The natural frequency of the cracked beam is found by the well known Finite Element (FEM) Software ANSYS. Modal analysis is carried out using the Block Lanczos method for finding the natural frequencies. First cantilever and Second simply supported boundary condition was applied by constraining the nodal displacement in both x and y direction. The results are tabulated in Table 2.1, Table 3.1 and Table 3.2. The five mode shapes of beam with and without crakes are shown in Fig.3.3, and Fig 3.4.

Table: 3.1. Natural Frequencies of Un- cracked beam (ANSYS)

	Natural Frequency in Hz				
Condition	**I st Mode**	**II nd Mode**	**III rd Mode**	**IV th Mode**	**Vth Mode**
Cantilever Beam	30.998	194.146	543.416	1064.620	1759.540
Simply Supported	248.307	807.587	1672.120	2840.270	4269.810

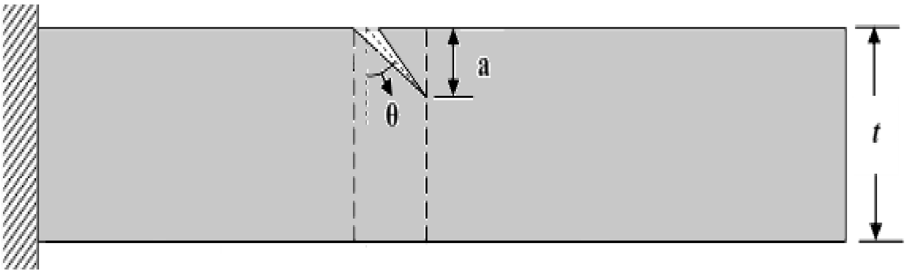


Figure 3.1: Cracked Beam Modeled in ANSYS

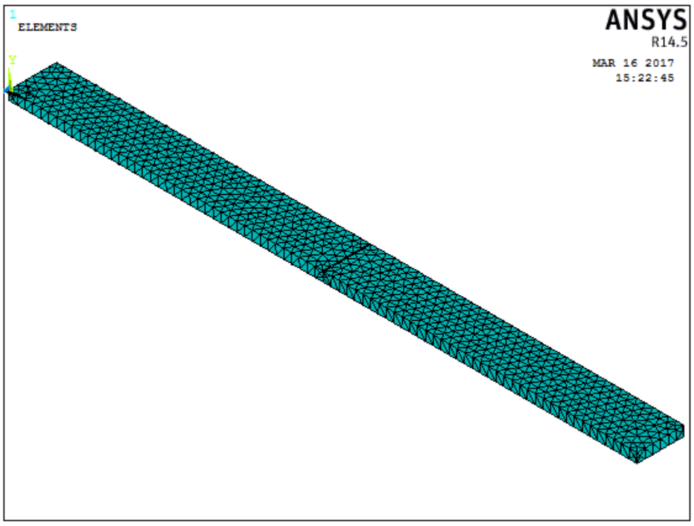
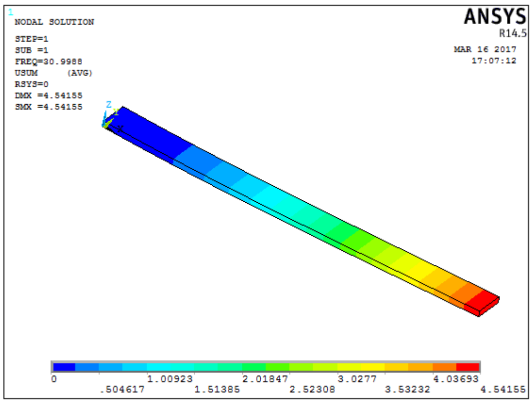
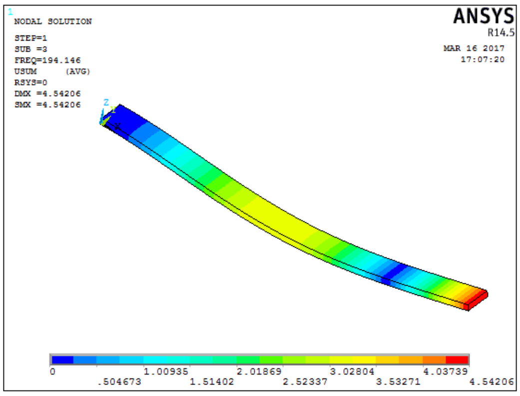


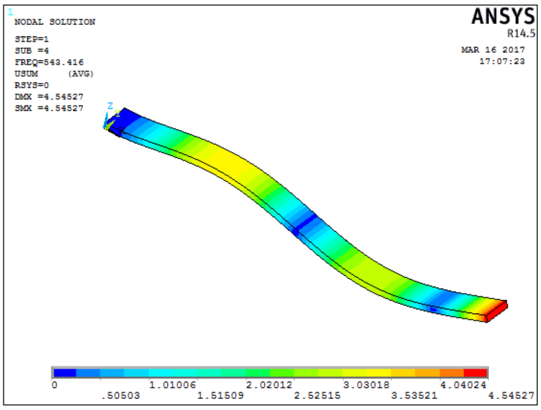
Figure 3.2:Mesh Model



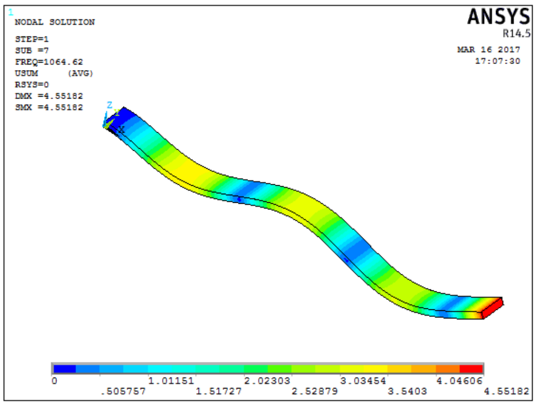
First Mode



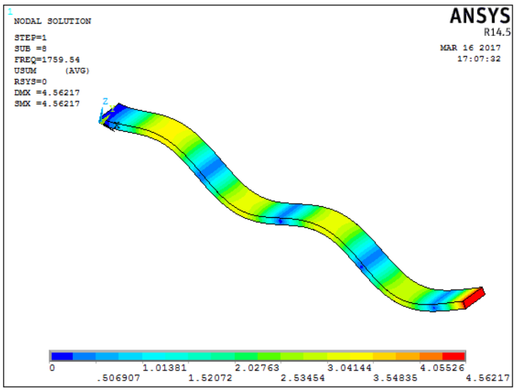
Second Mode



Third Mode

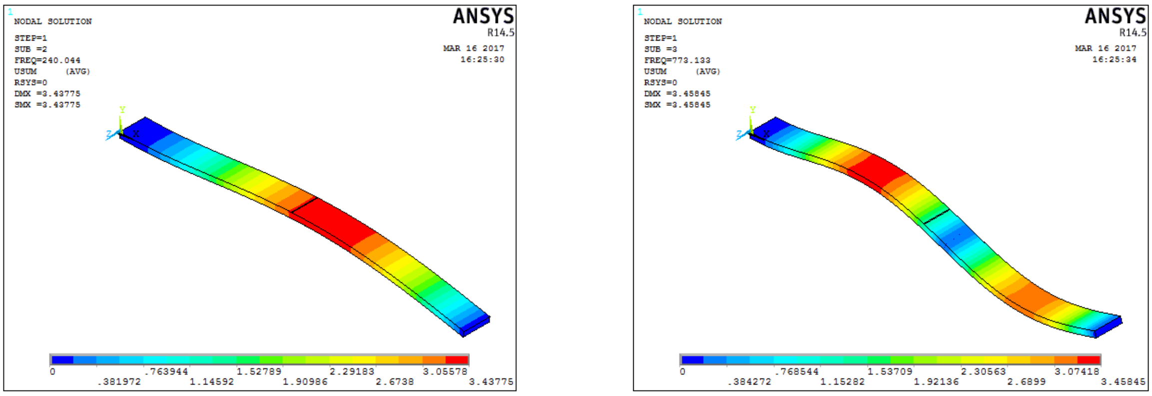


Fourth Mode

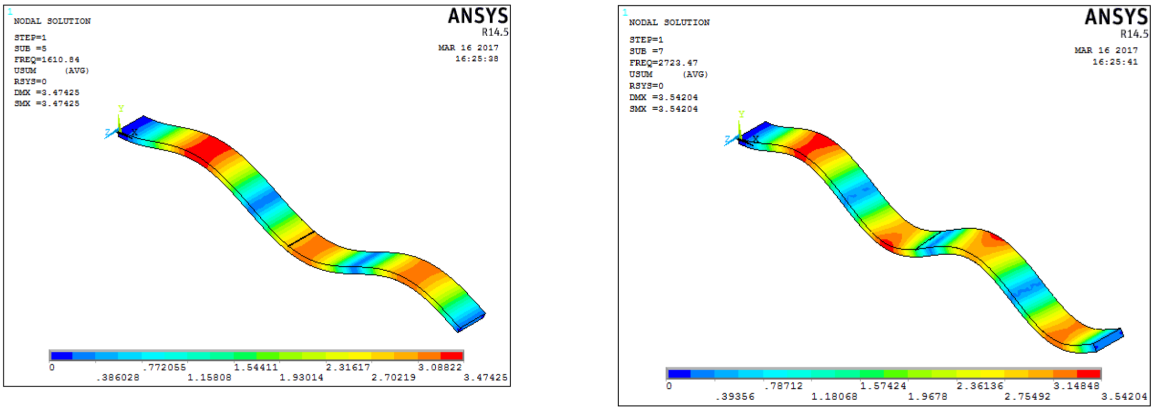


Fifth Mode

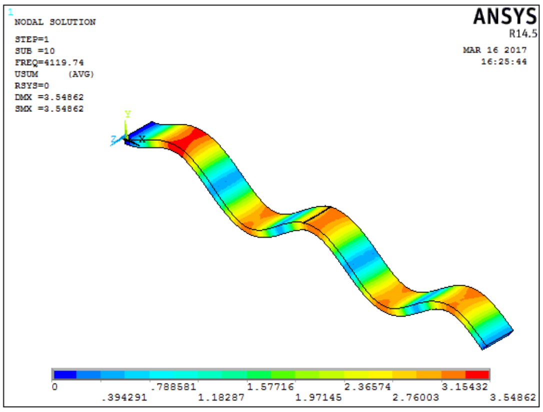
Figure 3.3: Mode Shape of Cantilever Un-cracked Beam



First Mode **Second Mode**



Third Mode **Fourth Mode**



Fifth Mode

Figure 3.4: Mode Shape of Cracked Simply Supported Beam (θ=150 and α= 0.1)

Table 3.2: Natural Frequencies of cracked cantilever beam with varies crack Inclination angle and depth of crack by Using ANSYS

Crack angle θ	Relative Crack Depth (α = a/t)	Natural Frequency in Hz				
		I st Mode	II nd Mode	III rd Mode	IV th Mode	V th Mode
0	0.1	55.1153	342.207	951.38	1867.4	3035.25
0	0.2	54.7553	339.599	945.402	1854.5	3017.22
0	0.3	55.3511	342.623	962.804	168.58	3059.29
15	0.1	55.218	341.673	954.059	1866.55	3054.72
15	0.2	54.539	337.282	954.137	1855.53	3021.03
15	0.3	55.4987	341.868	963.736	1863.88	3057.19
30	0.1	55.5071	342.708	955.385	1865.61	3056.76
30	0.2	54.9441	340.851	949.807	1859.55	3028.29
30	0.3	54.7902	338.326	948.04	1843.69	3039.25
45	0.1	55.3	344.192	954.642	1880.91	3054.28
45	0.2	54.607	339.651	944.81	1858	3015.91
45	0.3	54.423	336.544	945.294	1845.01	3038.04

Table 3.3: Natural Frequencies of cracked simply supported beam with varies crack Inclination angle and depth of crack by Using ANSYS

Crack angle θ	Relative Crack Depth (α = a/t)	Natural Frequency in Hz				
		I st Mode	II nd Mode	III rd Mode	IV th Mode	V th Mode
0	0.1	240.111	771.29	1611.34	2711.71	4131.15
0	0.2	238.227	765.661	1598.02	2692.48	4093.94
0	0.3	241.208	776.544	1612.6	2730.78	4127.38
15	0.1	240.044	773.133	1610.84	2723.47	4119.74
15	0.2	237.063	766.878	1598.36	2692.05	4094.49
15	0.3	240.803	776.83	1607.76	2730.66	4112.4
30	0.1	240.637	775.308	1613.19	2728.61	4120.4
30	0.2	238.861	769.381	1602.38	2703.66	4108.11
30	0.3	237.72	766.822	1596.44	2701.75	4088.85
45	0.1	241.279	774.212	1622.05	2725.76	4148.31
45	0.2	238.049	763.658	1603.26	2688.43	4104.09
45	0.3	236.383	765.513	1593.29	2697.66	4082.24

IV. RESULT AND DISCUSSION

Fig.3.1 shows the model of the beam and fig. 3.2. Shows the meshing of the beam. Fig 3.3 and 3.4 shows that natural frequencies of the beam with and without inclined edge crack at various crack inclination and crack depths for first, second, third, fourth and fifth modes of vibration respectively with cantilever and simply supported boundary condition. Results show that there is an appreciable variation between natural frequency of cracked and un-cracked beam with cantilever and simply supported condition. It is observed that natural frequency of the cracked beam decreases both with increase in crack inclination and crack depth due to reduction in stiffness. It appears therefore that the change in frequencies is not only a function of crack depth and crack inclination but also of the mode number.

V. CONCLUSION

It has been observed that the natural frequency changes substantially due to the presence of cracks depending upon inclination and depth of cracks. The results of the crack parameters have been obtained from the comparison of the results of the un-cracked and cracked cantilever beam during the Modal analysis using ANSYS software. When the crack location and crack inclination are constant, but the crack depth increases. The natural frequency of the cracked beam decreases with increase the crack depth. It has been observed that the change in frequencies is not only a function of crack depth, and crack inclination, but also of the mode number. As largest effects are observed at the crack inclination 450 and depth ratio is 0.3 on cantilever beam we can say, decrease in frequencies is more for a crack located where the bending moment is higher.

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